U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

INDUSTRIAL EFFICIENCY & DECARBONIZATION OFFICE

Developing a Roadmap and Strategy for Industrial Decarbonization

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HFTO Workshop: Hydrogen Infrastructure Strategies to Enable Deployment in High-Impact Sectors

January 18, 2024 | Denver, CO

Argonne NATIONAL LABORATORY

NREL Transforming ENERGY

OAK RIDGE National Laboratory

BERKELEY LAB Lawrence Berkeley National Laboratory

energetics Clean Energy Consulting

Building a Net-zero, Clean Energy Future

The U.S. industrial sector (manufacturing, agriculture, mining, and construction) accounts for:

33% of the nation's primary energy use

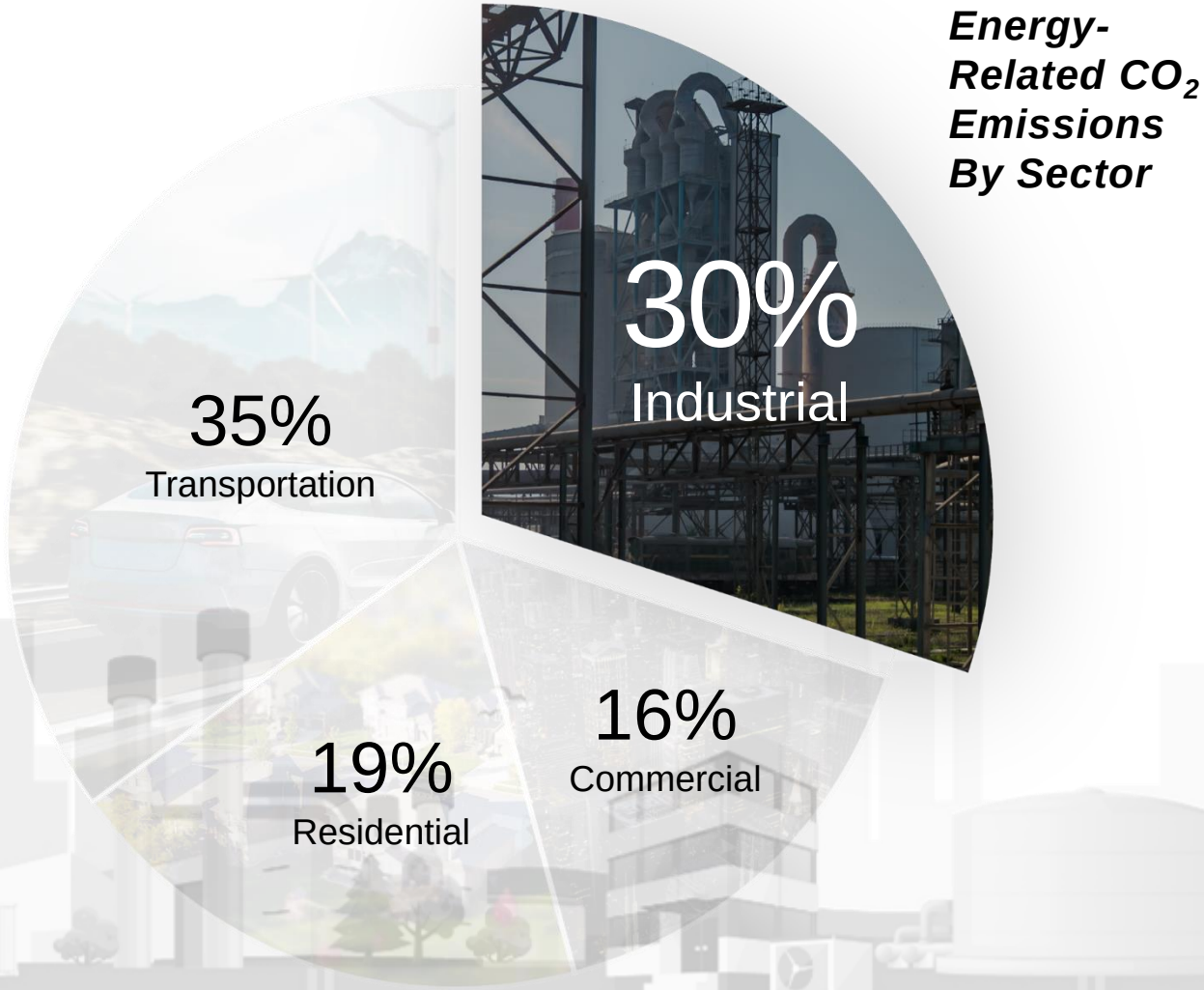
30% of CO_2 emissions

Anticipated industrial sector energy demand growth of 30% by 2050 may result in a:

17% CO_2 emissions increase*

*EIA, *Annual Energy Outlook 2021 with Projections to 2050*.

Energy-Related CO_2 Emissions By Sector



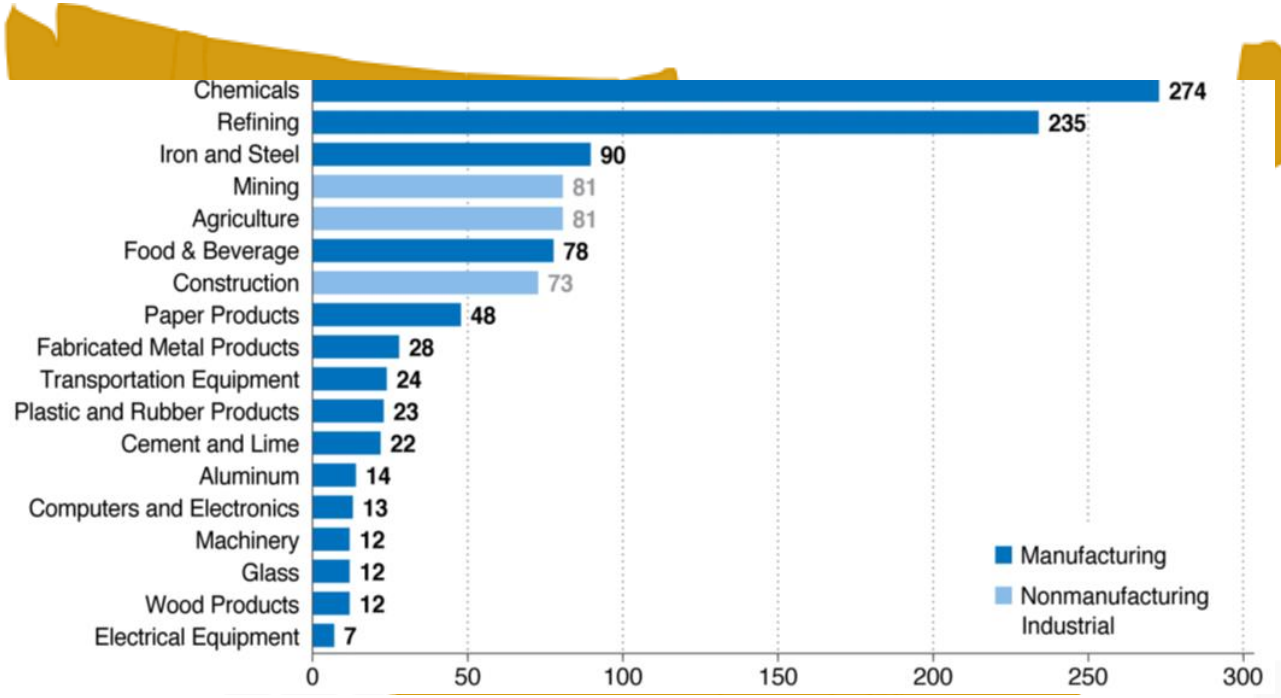
Decarbonizing Industry is an Opportunity for America's Economy

U.S. manufacturing subsector…

CONTRIBUTES
$2.79 trillion to the U.S. Economy

GENERATES
12% of U.S. GDP

SUPPORTS
11.2 million jobs



While working to DECREASE CO_2 emissions

We need to work across all the industrial subsectors to decrease overall emissions

U.S. Census Bureau Annual Survey of Manufactures & U.S. Bureau of Economic Analysis data for 2021

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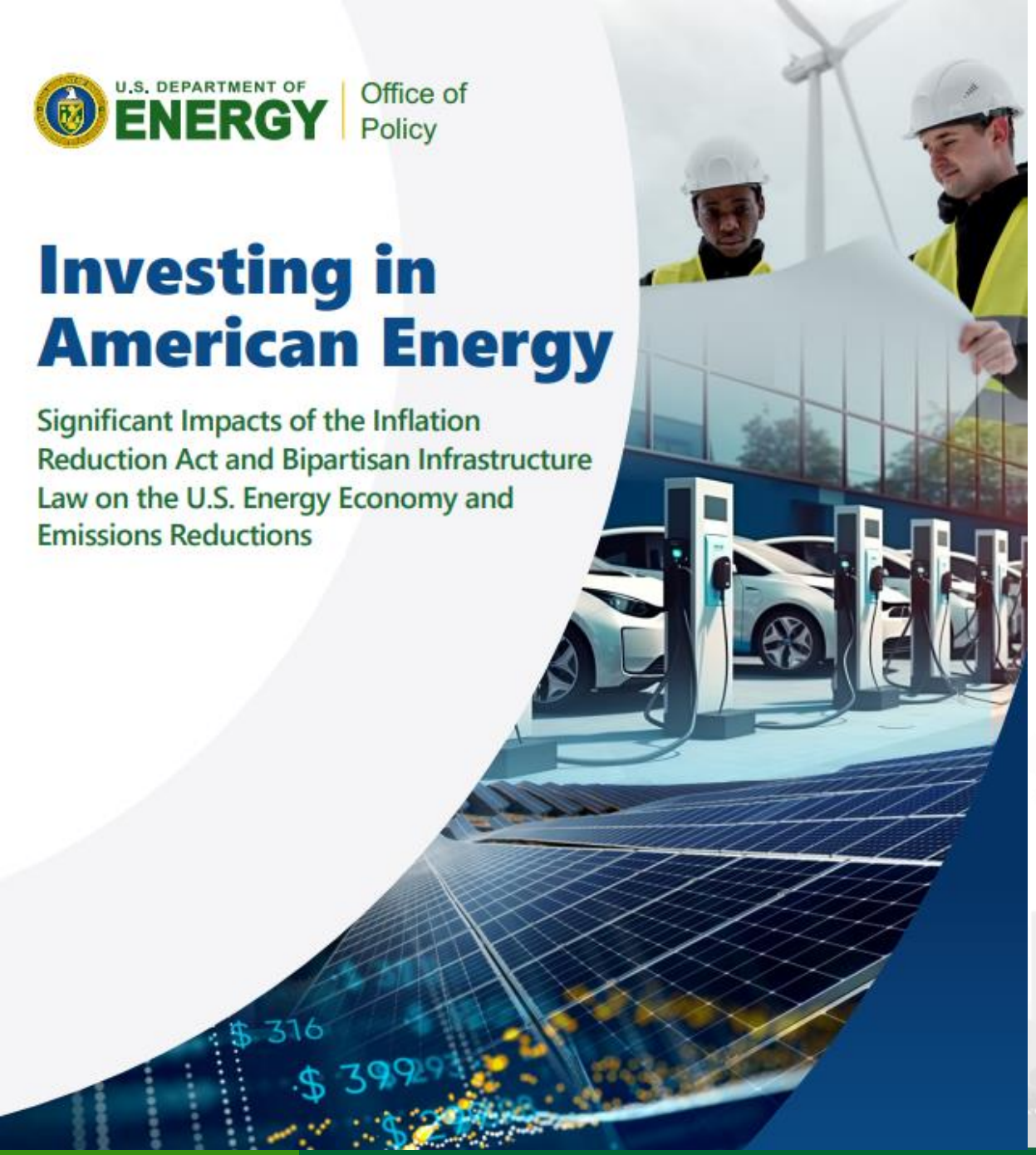
Investing in American Energy

Significant Impacts of the Inflation Reduction Act and Bipartisan Infrastructure Law on the U.S. Energy Economy and Emissions Reductions



The Inflation Reduction Act of 2022 (IRA) and Bipartisan Infrastructure Law of 2021 (BIL) together represent a historic investment of more than **$430 billion toward modernizing the American energy system**.

Systemic Barriers to Industrial Decarbonization

Investment scale → In the range of

$700 Billion – 1.1 Trillion

just for 8 industrial sector of focus in the IRA :


Chemicals


Refining


Iron & Steel


Food & Beverage


Cement


Pulp & Paper


Aluminum


Glass

Estimated that

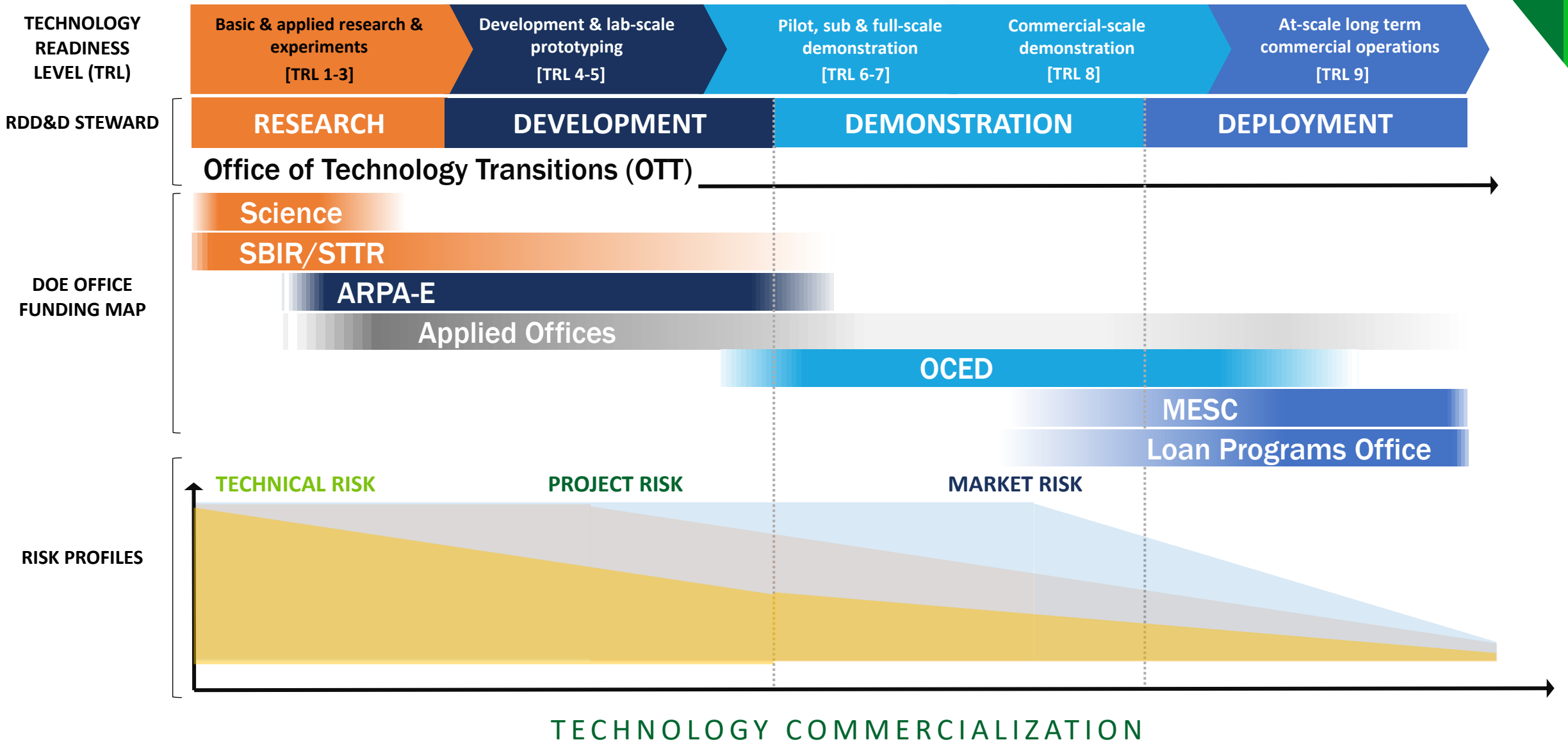
60% 

by 2030 will come from technologies that are not net-positive decarbonization levers with existing IRA tax credits or require further R&D to address

Targeted investment for research, development, and pilot-scale demonstrations is a need and opportunity for U.S. manufacturing

DOE Pathways to Commercial Liftoff; Industrial Decarbonization https://liftoff.energy.gov/wp-content/uploads/2023/10/LIFTOFF_DOE_Industrial-Decarbonization_v8.pdf

Roles Across Research, Development, Demonstration & Deployment (RDD&D) Continuum



Industrial Efficiency and Decarbonization Office (IEDO)

Vision: An efficient and competitive industrial sector with net-zero greenhouse gas emissions by 2050.

Mission: IEDO leads the development and accelerates the adoption of sustainable technologies that increase efficiency and eliminate industrial GHG emissions

To meet the ev
Industrial Effic
Assistance Pa
Combined Hea
set of technol

U.S. Department of Energy's (DOE) Industrial Efficiency and Decarbonization Office (IEDO) announced renewed funding for the Rapid Advancement in Process Intensification Deployment (RAPID) Institute — one of DOE's seven Manufacturing USA Institutes. The 5-year, $40 million investment will propel research, development, and demonstrations (RD&D) of advanced process technologies to enable more resilient, lower cost, and reduced energy and carbon footprint manufacturing in the process industries. This includes the production of chemicals and fuels, which account for more than a third of all U.S. industrial emissions and energy consumption.

ENERGY- AND EMISSIONS-INTENSIVE INDUSTRIES

Chemicals, Iron & Steel, Food & Beverages, Cement, Paper & Forest Products

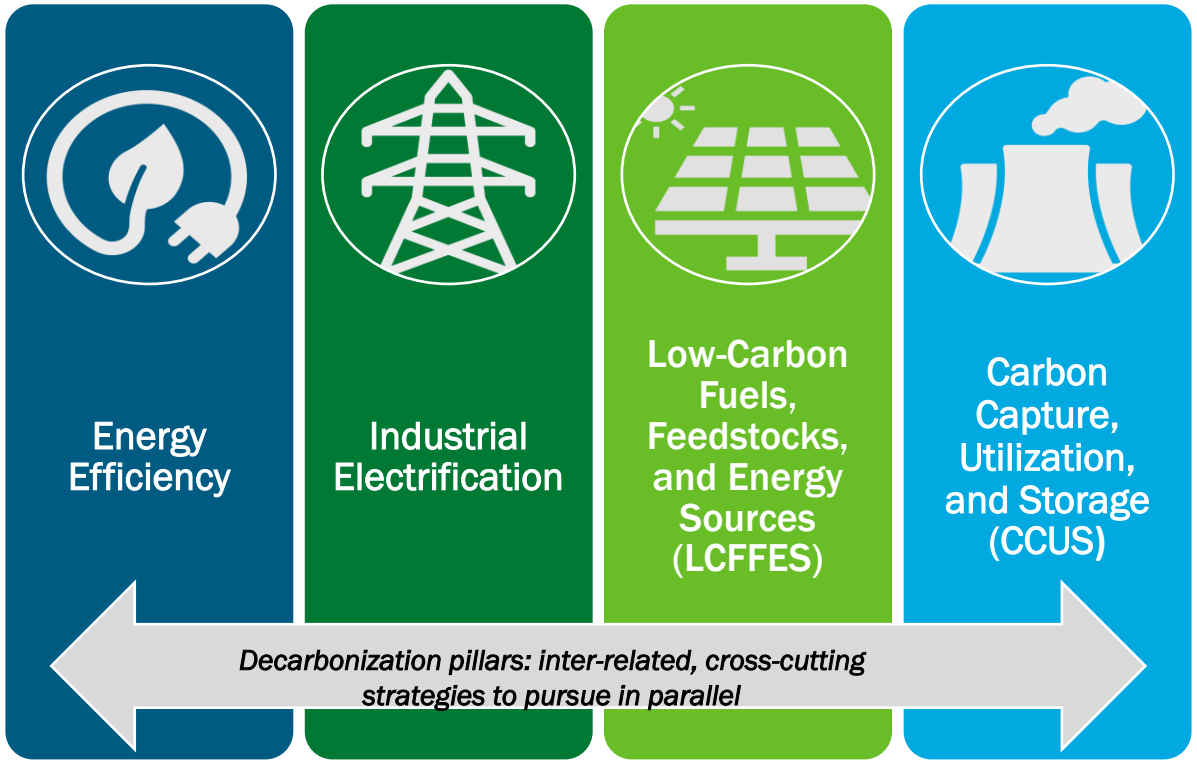
CROSS-SECTOR TECHNOLOGIES

Decarbonizing Process Heat
Low-Carbon Fuels and Feedstocks
Water and Wastewater
Energy Efficiency Technologies

Onsite Energy
Better Plants
Energy Management Programs
Industrial Technology Validation
Water Technical Assistance

DOE Industrial Decarbonization Roadmap - Pillars and Sector Focus Areas

Industrial Decarbonization Pillars



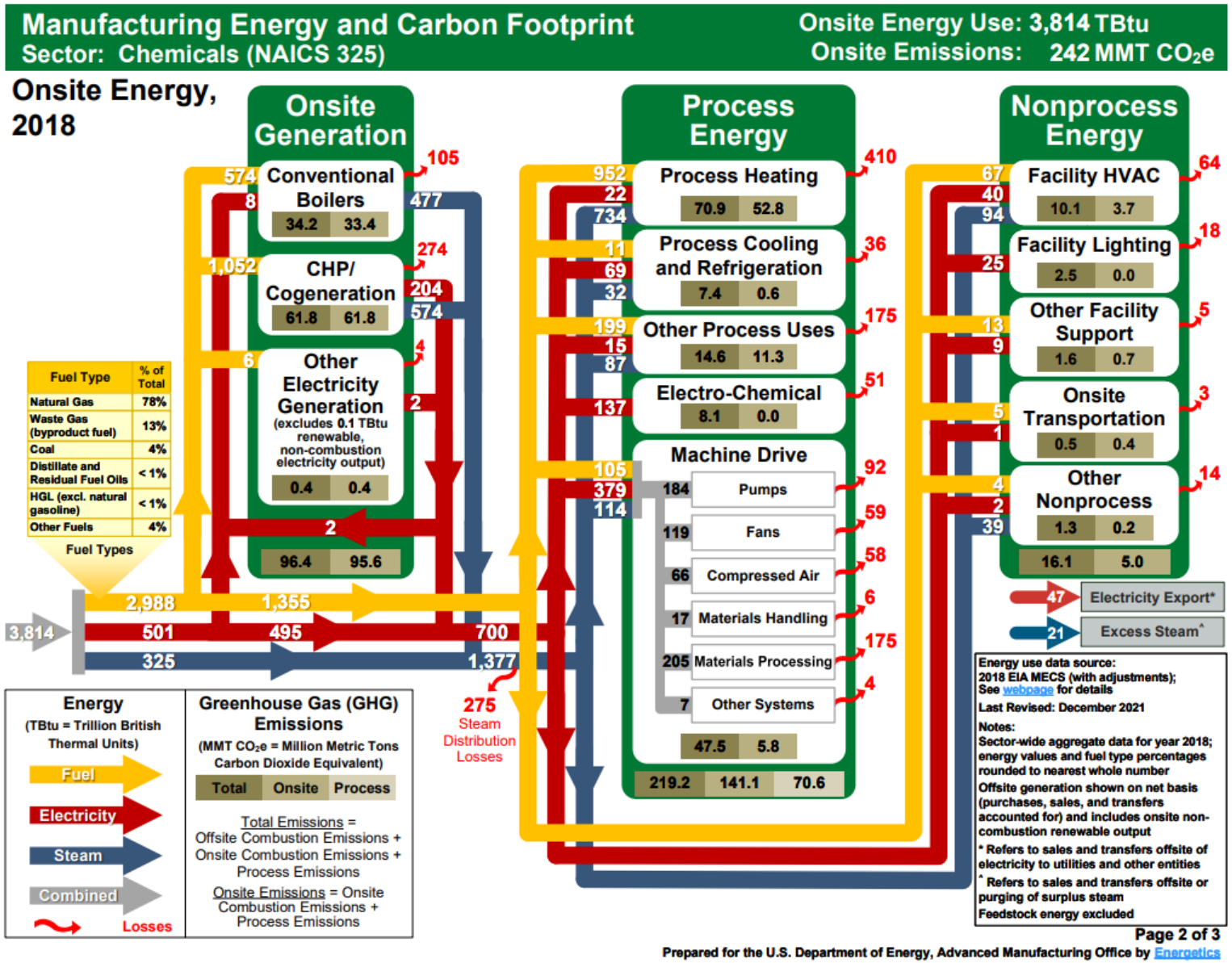
Chemicals

7,519 TBtu

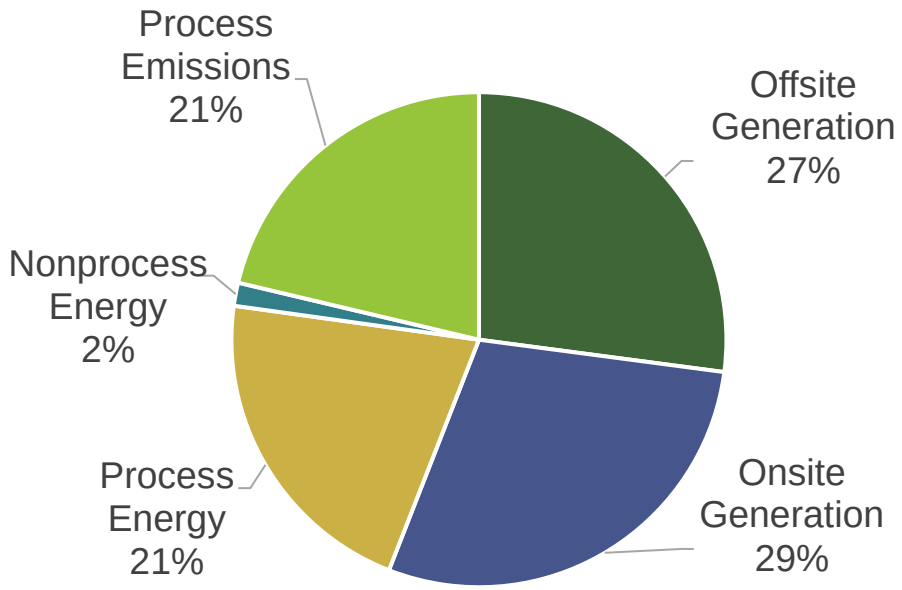
274 MMT energy-related CO_2e

Annual Energy Outlook 2021 with Projections to 2050," U.S. Energy Information Administration, February 3, 2021, https://www.eia.gov/outlooks/archive/aeo21/. See Table 19. Energy-Related Carbon Dioxide Emissions by End Use.

Manufacturing Energy & Carbon Footprints - Chemicals



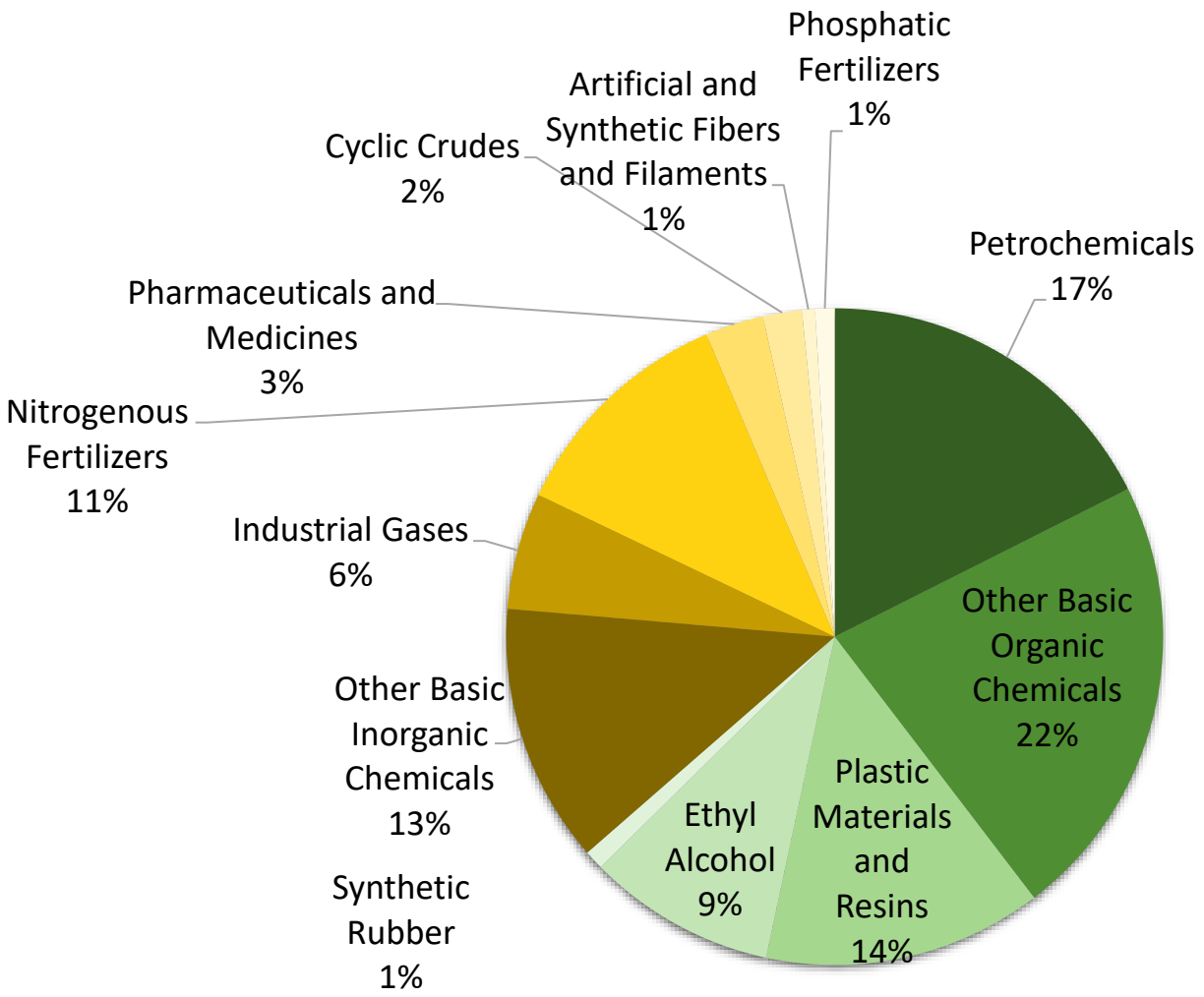
Distribution of GHG emissions in 2018

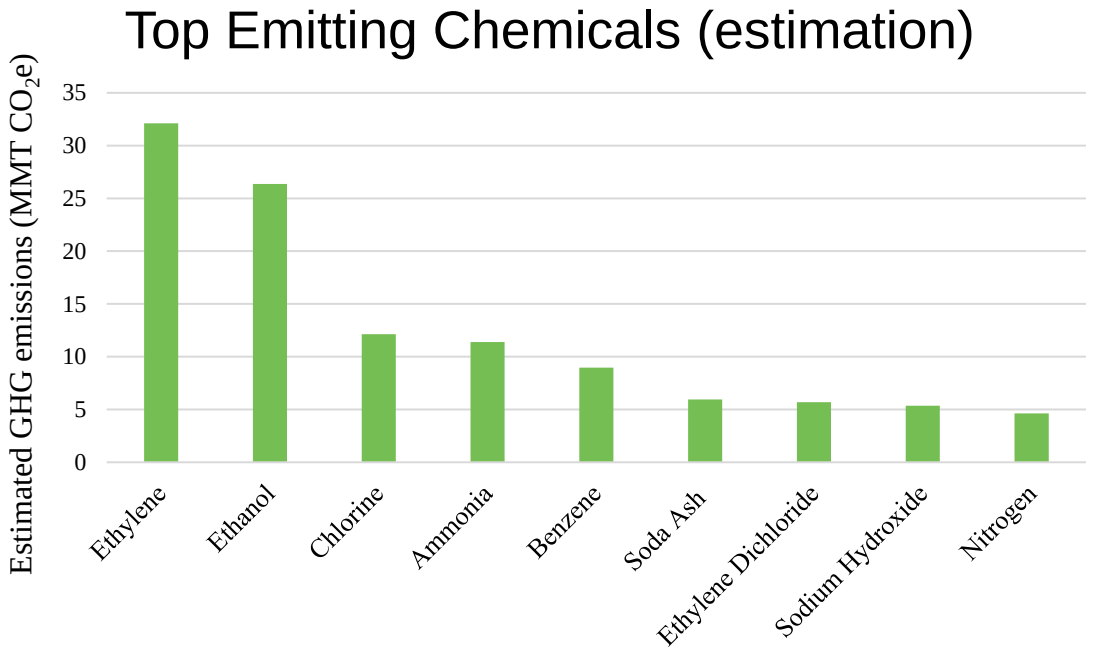


Onsite emissions represent **63%** of overall chemicals sector emissions

Manufacturing Energy and Carbon Footprints: https://www.energy.gov/eere/iedo/manufacturing-energy-and-carbon-footprints-2018-mecs

Emissions Distributed Across Chemicals Sector

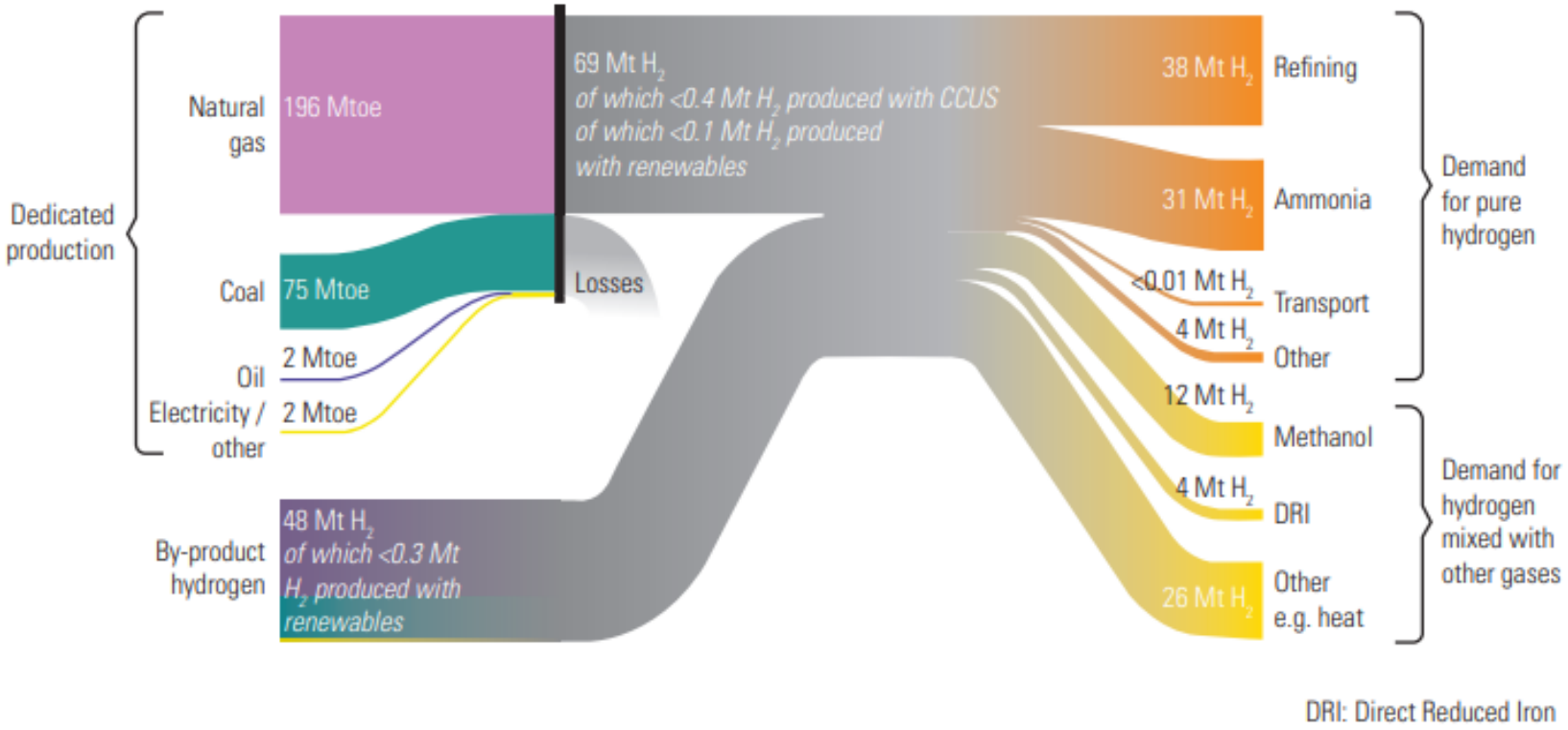




The 74 High Volume Energy Intensive Chemicals
Majority between 1 MMT and 0.5 MMT CO_2 annually

Manufacturing Energy and Carbon Footprints: https://www.energy.gov/eere/iedo/manufacturing-energy-and-carbon-footprints-2018-mecs
Manufacturing Energy Bandwidth Studies: https://www.energy.gov/sites/default/files/2015/08/f26/chemical_bandwidth_report.pdf

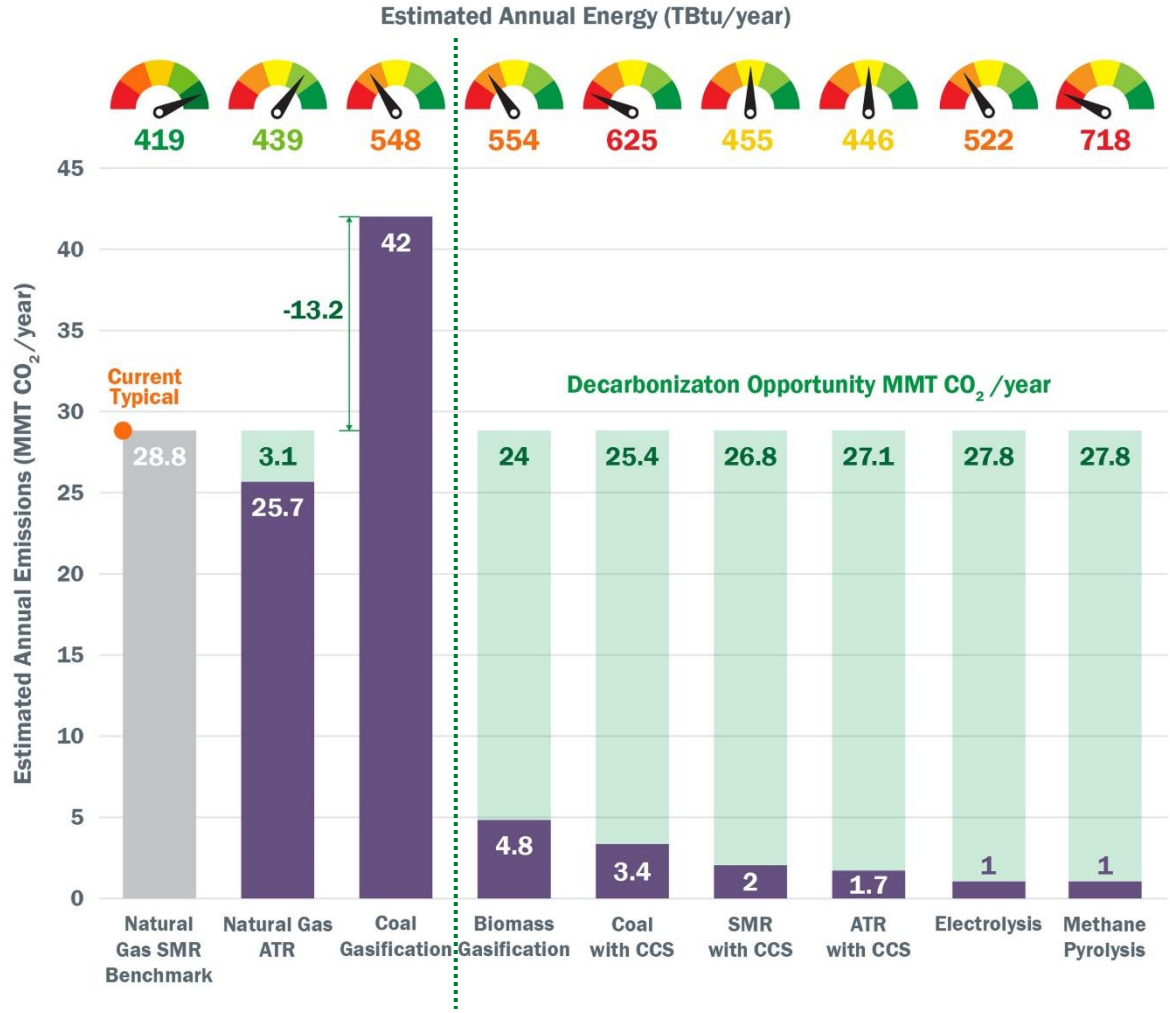
Worldwide Hydrogen Value Chains



- Ammonia decarbonization and H_2 decarbonization strategies must be considered together
- 90% of ammonia's GHG emissions are related to the H2 production step[1,2]
- Ammonia is the 2nd largest H_2 market today[3] and accounts for ~1/4 of all H_2 produced[4]

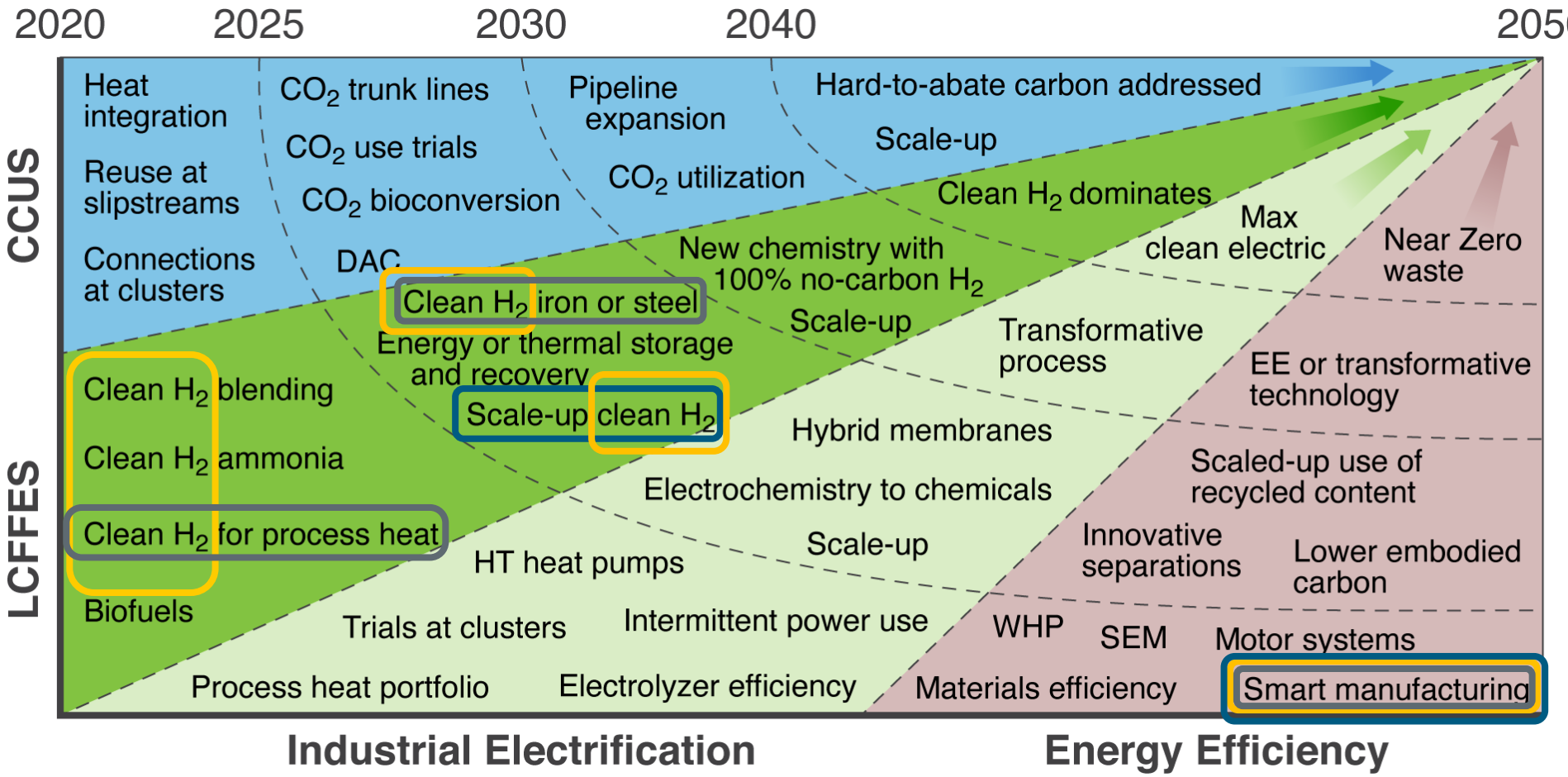
1. https://www3.weforum.org/docs/WEF_NetZero_Industry_Tracker_2022_Edition.pdf
2. https://royalsociety.org/-/media/policy/projects/green-ammonia/green-ammonia-policy-briefing.pdf
3. https://industrialinnovation.org/wp-content/uploads/2023/05/The-Landscape-of-Clean-Hydrogen.pdf
4. https://www.energy.gov/sites/prod/files/2020/07/f76/USDOE_FE_Hydrogen_Strategy_July2020.pdf

Ammonia Decarbonization Technology Benchmarking



RSC Policy Briefing, Ammonia: zero-carbon fertilizer, fuel and energy store, 2020, https://royalsociety.org/topics-policy/projects/low-carbon-energy-programme/green-ammonia/
IEA, Ammonia Technology Roadmap, 2021, Table 1.2, https://www.iea.org/reports/ammonia-technology-roadmap
EPA, Inventory of U.S. Greenhouse Gases and Sinks: 1990 – 2019, https://www.epa.gov/sites/default/files/2021-04/documents/us-ghg-inventory-2021-main-text.pdf.
INL, Nuclear-Integrated Ammonia Production Analysis, 2010, https://art.inl.gov/

Industrial Decarbonization Barriers: Systems Challenges



Landscape of major RD&D investment opportunities for industrial decarbonization between now and 2050.

LCFFES = Low Cost Fuels, Feedstocks, and Energy Sources; **CCUS** = Carbon Capture Utilization and Storage

Industrial GHGs require approaches at multiple levels:

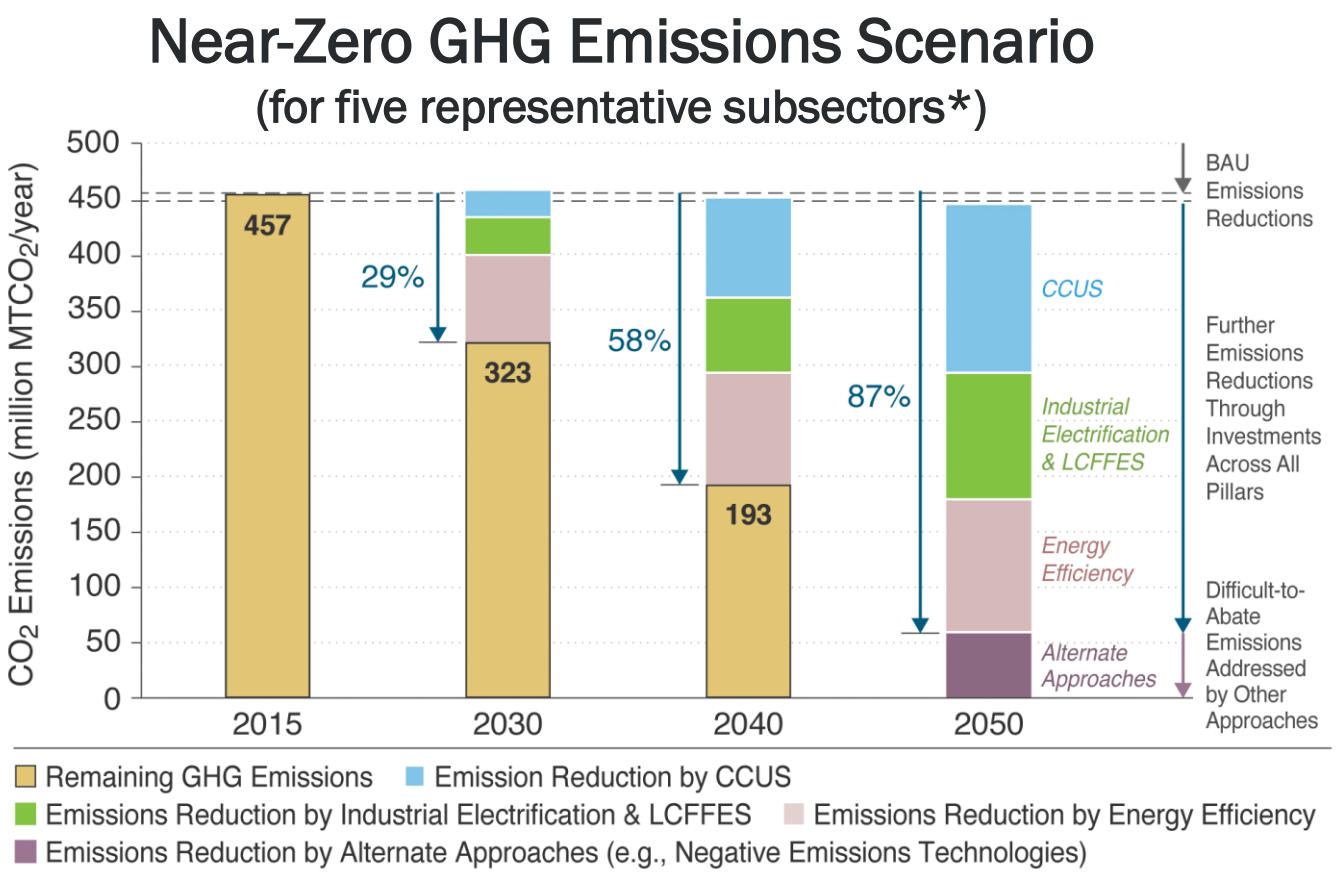
- Core process
- Facility
- Beyond plant bounds

What are the implications of:

- Expanded H_2 generation & use
- New thermal energy sources & systems
- Smart manufacturing, automation, & data analytics
- Transition to clean electricity
- Policies

DOE Industrial Decarbonization Roadmap, Sept. 2022 https://www.energy.gov/sites/default/files/2022-09/Industrial%20Decarbonization%20Roadmap.pdf

Industrial Decarbonization Recommendations



Roadmap Recommendations

- Advance Early-Stage RD&D
- Invest in Multiple Process Strategies
- Scale through Demonstrations
- Address Process Heating
- Decarbonize Electricity Sources
- Integrate Solutions
- Conduct Modeling and System Analyses
- Engage Communities, Develop a Thriving Workforce

***Subsectors included in Roadmap analysis:** Iron & Steel, Chemicals, Food & Beverage, Petroleum Refining, and Cement. *(Near zero GHG scenario, excluding feedstocks.*

DOE Industrial Decarbonization Roadmap, Sept. 2022. https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap

Thank you

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